Defense Science Board Task Force

on

Contributions of Space Based Radar to Missile Defense

June 2004

Office of the Under Secretary of Defense
For Acquisition, Technology, and Logistics
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OFFICE OF THE SECRETARY OF DEFENSE
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WASHINGTON, DC 20301-3140

DEFENSE SCIENCE
BOARD

MEMORANDUM FOR ACTING UNDER SECRETARY OF DEFENSE
(ACQUISITION, TECHNOLOGY & LOGISTICS)

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Contributions of Space Based Radar to Missile Defense

I am pleased to forward the final report of the DSB Task Force on Contributions of Space Based Radar (SBR) to Missile Defense. While the primary missions of SBR are moving target indication and synthetic aperture imaging, the value of this inherent capability to missile defense was assessed by the Task Force.

The Task Force explicitly discussed four areas in their report on potential contribution an SBR capability could provide to missile defense. They have provided specific recommendations in each of these areas.

I endorse all of the Task Force's recommendations and encourage you to review the report.

William Schneider, Jr.
DSB Chairman

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OFFICE OF THE SECRETARY OF DEFENSE
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DEFENSE SCIENCE BOARD

MEMORANDUM TO THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Defense Science Board task force on Contributions of Space Based Radar to Missile Defense

Attached is the report of the Defense Science Board Task Force on the Contribution of a Space Based Radar (SBR) in Missile Defense. This was a rapid response task to answer specific questions. This report provides answers to those questions. It also raises additional questions that warrant attention beyond that possible in the limited time available.

The report addresses four areas of potential SBR contribution to missile defense. They are: pre-launch location, monitoring, and tracking; launch detection and early trajectory measurement; trajectory tracking and; discrimination. The discussion of the first three is unclassified. The fourth area is necessarily classified Secret. Since discussion of all four areas is needed for adequate coverage of the subject, the overall report is classified. A limited unclassified version will be provided separately.

Robert Hermann

Dr. Robert Hermann
Co-Chair

Larry D. Welch

Gen Larry D. Welch, USAF (Ret)
Co-Chair

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SUMMARY

THE TASKING

In accordance with the National Defense Authorization Act for FY 2004, the Defense Science Board (DSB) was asked to assess the potential contributions of a Space Based Radar (SBR) to missile defense. In response, the Undersecretary of Defense for Acquisition, Technology and Logistics (USD (AT&L), and the Director, Missile Defense Agency (MDA) directed that the DSB Task Force on the Contribution of a Space Based Radar to Missile Defense perform the following tasks:

- Assess the impact of adding a missile defense mission on the ability of SBR satellites to conduct their primary missions;
- Assess how different SBR architectures and technical approaches might affect the ability of the satellites to achieve their primary missions and to contribute to missile defense;
- Assess the value of potential SBR capabilities in the context of the family of sensors being developed by the Missile Defense Agency; and
- Recommend any future actions that might be desirable related to SBR contributions to missile defense.

THE BASELINE SYSTEM DESCRIPTION AND PERFORMANCE

Since the program remains in the design stage, with two contractors selected for this phase of the effort, the baseline system definition continues to evolve. Further, the system is to use the spiral development approach with Increment 1 deployment beginning in 2010-2012.

- SBR is to provide global, all weather, day/night, persistent access of areas of interest with Surface Moving Target Indication (SMTI), Synthetic Aperture Radar (SAR) imaging, and High Resolution Terrain Information (HRTI).
- The system could be some combination of Low Earth Orbit (LEO) satellites at a nominal altitude of 1,000 km and Medium Earth Orbit (MEO) at a nominal altitude of 10,000 km.
- The SMTI requirement is to track a 10-decibel (DB) target at 2,800km – a truck size vehicle with about a $10m^2$ radar cross section.
- LEO will support both the SMTI and SAR imaging requirements with reasonable combinations of power and aperture.
  - The options for a LEO system are characterized as 1X, 2X, and 3X. Available space launch capabilities could deliver three 1X systems on a single vehicle. The same space launch vehicle could deliver only one 3X system. For the 1X system, the power-aperture (power in kilowatts x aperture in $meters^2$) is 35 kwm^2. For reference, the average radiated power aperture for the Aegis radar system is 485 kwm^2.
  - A LEO constellation requires some 21 satellites to provide persistent global access. A discussion of what constitutes persistence is discussed in a later section.
  - As an example of the performance of smaller constellations, the nominal Increment 1 system of 9 satellites in LEO would provide access to North Korea with at least one satellite some 55-60% of the time.

– MEO will support SMTI with fewer satellites but would require long processing times to provide the needed quality of SAR images.

BOTTOM LINE

There are four major areas of potential application of SBR capabilities to support the missile defense goal of evolving to an integrated, layered system to defeat missiles of all ranges in all phases of flight to defend the United States, forces deployed, and allies. The following provides the bottom line findings in each of the four areas and bottom line findings relative to the increased command and control and battle management integration challenge associated with exploiting the SBR potential. The remainder of the report expands on these points.

As an overarching finding, the task force believes that the Space-Based Radar has the potential for substantial contributions to ballistic missile defense, providing capabilities and access that are difficult to achieve with surface-based sensors

Pre-launch location, monitoring, and tracking

- The baseline Surface Moving Target Indication (SMTI) and Synthetic Aperture Radar (SAR) imaging capabilities of the SBR could make a major contribution to locating and monitoring ballistic missile installations of interest and to tracking mobile systems.
- Both SMTI and SAR imaging capabilities are needed, with agile change between modes, to maintain track and monitor selected vehicles.
- An expansion in numbers beyond Increment 1 will be needed to provide continuous monitoring during times and at places of high interest.

  - A nominal Increment 1 capability - a 9-satellite constellation in LEO - could provide access to North Korea 55-60% of the time.
  - A 21-satellite constellation could provide near full-time access to multiple theaters of interest.

- With less than a 21-satellite constellation, a combination of space-based and other assets will be needed to provide continuous access during times and at places of high interest. Continuous access does not imply unlimited continuous tracking. Tracking capability is discussed later in the report.
- **The Department needs to explicitly define the evolving system of systems that will provide near continuous access during times and in places of high interest.**

Launch detection and early trajectory measurement

- Air Moving Target Indication (AMTI) track capability could be added to Increment 1 with low impact on cost and schedule if included in the initial design. AMTI could provide early warning of launch from known launcher locations and some capability to search a given area on the surface for launches from unknown sites. SBR AMTI would not have a capability to search airspace and must instead either be cued by another system or maintain track from the point of launch.
  - Using conservative assumptions, about 10% of a single satellite's SMTI/AMTI resources are needed for each monitored site.
  - Using other assumptions, SBR, using AMTI, could monitor multiple sites and also search a significant area for launches from unknown sites.

  - Early launch detection (before cloud break) could cut valuable tens of seconds from the time to cue other missile defense systems.

- The AMTI capability could also provide sufficient trajectory information to commit an interceptor for earliest engagement.
  - Single satellite access should be capable of providing information on a single digit number of simultaneous launches.
  - Earliest commitment is critical to success for boost/ascent phase and some mid-course intercepts.
- **The potential value of AMTI capability warrants adding it to the SBR program. To be useful for this mission, the constellation must eventually provide near continuous access during times and at places of high interest.**

Trajectory Tracking

- The baseline SBR is to have an inherent capability to measure velocity and velocity changes of major components of a missile system that are above the horizon with useful precision. Cueing is required for SBR to acquire the missile.
- This capability would provide an intercept error basket precise enough to direct the interceptor to its required acquisition and maneuver basket.
- **The Missile Defense Agency needs to include the trajectory tracking capability of the baseline SBR in plans for the overall sensor architecture for an integrated missile defense.**

Discrimination- discussion classified and included in classified report

Command and control (C2) and battle management (BM) integration

Exploiting SBR capabilities to contribute to ballistic missile defense adds significant complexity to the C2 and BM integration task for the SBR system. The added challenges include:

- Low latency and persistent SMTI and SAR imaging access to monitor ballistic missile installations of interest and to track vehicles of interest moving from such installations.
- Managing simultaneous demands to include:
  - Providing continuous AMTI access, during periods and at places of high interest, of known missile launcher locations,
  - Conducting AMTI search of designated areas, and
  - Performing other high-priority SBR missions.
- Adding SBR capabilities for missile defense will place new demands on a number of key functions, e.g., signal processing, software development, communication links, and off-board system updates. An aggressive technology development and transition program would be needed to provide a netted, integrated, computer aided command and control and battle management system.

DISCUSSION

PERSISTENCE – SMTI AND SAR IMAGING

The concept of persistence does not lend itself to a single metric. It will depend on the nature of the objects of interest, the dynamics of the situation, and the supported task – detect, track, identify, and/or engage. E.g., persistent monitoring of the status of construction of a missile site might demand a weekly revisit using SAR imaging capabilities. Persistent monitoring of a missile launch site in a ready to launch status, using Air Moving Target Indicator (AMTI) track capability might require a revisit every few seconds. Tracking a large moving unit might require an SMTI revisit every few minutes while tracking a single vehicle might require a revisit each tens of seconds.

In any case, selecting and tracking specific objects of interest will require a capability to change rapidly between SMTI and SAR imaging capabilities. SAR imaging will be required to identify the specific locations and vehicles of interest before movement starts. SMTI can then track the moving objects but will lose tracking and monitoring when the vehicle stops. An approach is to wait for movement to resume. However, SMTI alone cannot determine that the new movement is the same vehicle. Only SAR imaging can provide that information. Further, in the case of tracking missile launchers, the need for information is even more critical when the vehicle stops since known systems must stop to launch.

POTENTIAL CAPABILITIES RELEVANT TO MISSILE DEFENSE

The following potential SBR capabilities, briefly described in the foregoing Bottom Line Summary section, in ascending order of cost and complexity, could contribute to missile defense. The impact on other missions and value of the potential contribution are discussed in the section on each capability.

Pre-launch location, monitoring, and tracking

Detection. Nominal SBR designs and constellations can search countries the size of North Korea or Iraq for moving targets of cross sections larger than about $10m^2$ about every 10 minutes. This would include moving missile Transport-Erector-Launchers (TELS). However, there can be thousands of $10m^2$ vehicles moving at any time in a country the size of Iraq. Targeted monitoring of specific areas based on the full set of intelligence, surveillance and reconnaissance capabilities to include SBR SAR imaging will be required to direct the SMTI capability at areas of interest.

Access and Performance. Access depends primarily on constellation orbit and size. The maximum range for a SAR imaging from satellites in LEO at 1,000 km is 2,800 km. For a 9-satellite constellation at 53 degrees inclination, the distance between satellites is about 8,800 km, so the probability that a satellite is in position to cover a given target area is about 65%. A 21-satellite system would provide essentially continuous access to multiple theaters of interest.

Wide area SMTI uses a high area scan rate to monitor areas of interest. For example, within its area of access, the system can monitor road junctions in a 1000x760km area every 10 minutes. It could also monitor movements from individual garrisons distributed over a total area of 400x400km every 10 minutes. A few dozen high value moving targets can be tracked in the high-resolution mode in a 125x125km area with a revisit every 30 seconds.

The system can provide HRTI worldwide.

The combination of SMTI and SAR imaging with a 21-satellite constellation in LEO would provide detection, tracking and identification of targets of interest in areas of interest. To be useful for tracking high interest individual targets such as missile TELS, it will also be important to ensure that the system has both SMTI and SAR imaging capability with high agility between these modes.

Impact on Other SBR Missions. Since this pre-launch location, monitoring, and tracking is part of the baseline design mission of the

SBR, there is no impact other than the need to add this task to the list of high priorities.

RECOMMENDATION

The Department needs to explicitly define the evolving system of systems that will provide continuous SMTI and SAR imagery access during times and at places of high interest.

Launch detection and early trajectory measurement

Mission Benefit. The presently planned missile defense system depends primarily on the Defense Support Satellite system (DSP) for global launch warning. Since DSP is an IR system, it cannot provide launch detection until cloud break. In addition it does not provide sufficient trajectory information for early commitment of missile defense interceptors. Consequently, to defend against short time of flight attacks, e.g., a forward-based radar is required. In the near term, the Aegis radar system is to provide that capability for launches from North Korea. In the longer term, a global system of forward sensors will be required.

With the system addition described below, the SBR could monitor known sites with high reliability and provide early engagement quality trajectory information for launches from known sites or when cued by other sensors. The system could also be used for uncued area search within a specified area.

SBR System Addition Operation and Performance. With the addition of a high pulse repetition frequency capability (HPRF) waveform, the SBR system should be able to screen out ground clutter outside of the main lobe directly below the satellite. That should provide for SBR to detect targets moving faster than a minimum detectable velocity (MDV). Further work by the SBR Program Office is required to quantify the cost and risk of this addition, but the needed radar components are available and the cost and risk should be low.

For this mode of operation to be most effective, The AMTI capability would need to be cued, which could be provided by the SMTI/SAR imaging capability of SBR or other surveillance assets to include IR systems when cloud conditions permit. Given such cues, a conservative estimate of the maximum AMTI dwell time required to detect a launch from a range of 2,800 km is less than 1 second. Against boosting missiles with larger radar cross-sections, the dwell time could be a fraction of a second. Considering expected initial missile acceleration, and the near vertical initial trajectory, the planned vertical dimension of the AMTI beam will ensure that the missile will remain within the beam size for at least 10 seconds.

Using other reasonable assumptions, single satellite access could provide the capability to monitor multiple sites of known location and search a designated area to detect launches from unknown locations. While this uncued search approach will not provide reliable access over large areas, the capability provides an added problem for an adversary since they cannot know what part of their territory is being scanned in this mode at any given time.

With the larger constellations needed for continuous access to ground target areas of interest, there will be more than one satellite providing access to a given area a significant percent of the time. In this case, the uncued search capability is significantly enhanced and/or the impact on other missions is reduced.

Impact on Other SBR Missions. Using conservative assumptions, a single satellite could monitor at least 10 missile sites within the satellite's area of access if all of the satellites MTI resources are devoted to that task. With the same conservative estimates, a single site could be monitored using about 10% of the single satellite's resources. With other reasonable assumptions, a much smaller percent of the satellite's resources would be needed for this level of contribution to missile defense. Building a SAR image at these ranges from a LEO satellite requires about 16 seconds. However, that process can be divided into shorter segments so that it would be possible to monitor multiple launch sites while also using some resources to meet SAR imaging needs. Again, with larger

constellations, more than one satellite will have access a significant percent of the time further reducing impact on other missions.

While adding the capability inevitably has some impact on cost and risk, the task force believes the impact to be low. Adding the HPRF capability displaces no currently planned performance.

Impact on the Ballistic Missile Defense Architecture. The 9-satellite system would not provide a useful early launch and trajectory warning capability since such a capability must be 24/7 during periods of high concern. With a 21-satellite constellation and the addition of HPRF, SBR could take over some, or perhaps all of the radar coverage tasks for launch and trajectory warning and free a system such as Aegis to devote more resources to other mission demands. However, this capability is not likely to be available before 2012 and the planned missile defense architecture is to provide forward based land or sea-based radars well before the planned first SBR deployment.

Further, given the need for high-resolution global radar access (or access with some other set of high-resolution sensors) for discrimination, just adding early launch and trajectory warning does not significantly reduce the need for the planned elements of the currently defined missile defense architecture.

Still, providing the needed forward-based high-resolution sensor access for the evolving integrated layered system may not be feasible using only surface-based systems. It seems likely that space-based assets will need to have an expanding role and is likely to be the preferred, perhaps the only feasible, approach to meeting some important sensor location demands for the boost-phase layer of missile defense.

RECOMMENDATION

Given the broader set of future missile defense needs, – multiple layers of ballistic missile defense, the global nature of the need, and the uncertain state of development for radar capabilities to meet these needs -- the SBR Program Office should examine and quantify the cost, and risk

of adding an AMTI capability and associated near real time processing and communications support.

- The Program Office should complete the assessment in time to design the added capabilities into Increment 1 of the SBR if such capability proves feasible at acceptable risk.
- To be useful for this mission, the SBR constellation must eventually provide near full-time access during times and at places of high interest.

The Missile Defense Agency should examine the cost, risk, and benefit of alternative means of providing the needed global access for early launch warning and trajectory measurement for the integrated, layered system to include the potential contribution of SBR AMTI track capability.

Trajectory Tracking and Discrimination- discussion classified and included in classified report

Command and control and Battle Management Integration

Pre-launch location, monitoring, and tracking. The command and control and battle management integration task is not appreciably changed by the addition of SBR to the intelligence, surveillance and reconnaissance (ISR) suite for many targets and operations. However, for the missile defense mission, since the need includes identifying the location of mobile TELS with low latency when they have the potential to launch, that is, when they stop moving, the timelines are more demanding than for most other operations. The need for low latency includes supporting pre-boost operations where there is eminent danger of a launch. Here the acceptable latency is driven by the responsiveness of attack assets. Highly responsive support for attack operations against a wide range of targets is a current mission of SBR. Low latency is a requirement to support early launch and trajectory warning when SBR is committed to that role. Here the acceptable latency is measured in a few seconds as discussed in the next paragraph.

Launch detection and early trajectory measurement. Tracking fast moving vehicles in flight has not previously been an objective of the SBR program. There will be demanding near real time ISR (which can include SBR) integration needs to ensure that SBR AMTI capability is cued with enough precision to ensure that a missile in early boost phase is in the SBR beam. While this is no more demanding for fixed missile sites than for other fixed targets, it is highly challenging for moving targets. SMTI will lose track on the TEL as it slows to below SMTI threshold speed. When this occurs, there must be highly agile switching to SAR imaging mode for the SRB satellite to monitor the TEL when it stops. There will also be added command and control and battle management demands beyond detection of the launch to meet the latency requirements to make early launch and trajectory warning useful. Again, the information must be available and usable within a very few seconds.

Early attention will be needed to the added integration challenge generated by adding and exploiting AMTI capability. There may be substantial impacts on the demands on onboard signal processing, software development, and communication links. Full integration of SBR capabilities into the Task, Post, Process, and Update (TPPU) paradigm is needed to fuse SBR data with data from other sensor sources to offer multi-phenomenology detection, discrimination, and designation (D3) benefits. Such a system will contribute significantly to generating knowledge instead of just data, to meeting time sensitive targeting and response timelines, and to providing users a capability to quickly re-task sensors to optimize coverage of the evolving situation.

Discrimination

There would, again, be significant increases in the demand on command and control and battle management systems. Further discussion on this topic is classified and included in the classified report.

RECOMMENDATION

A decision to add new capabilities to the SBR to serve the missile defense mission must be accompanied with specific changes to the programs to provide integration of SBR information into missile defense command and control and battle management systems.

APPENDIX A: RECOMMENDATIONS

Pre-launch location, monitoring, and tracking

The Department needs to explicitly define the evolving system of systems that will provide continuous SMTI and SAR imaging access during times and at places of high interest.

Launch detection and early trajectory measurement

Given the broader set of future missile defense needs, – multiple layers of ballistic missile defense, the global nature of the need, and the uncertain state of development for radar capabilities to meet these need -- the SBR Program Office should examine and quantify the cost, and risk of adding an AMTI capability and associated near real time processing and communications support.

- The Program Office should complete the assessment in time to design the added capabilities into Increment 1 of the SBR if such capability proves feasible at acceptable risk.
- To be useful for this mission, the SBR constellation must eventually provide near full-time access during times and at places of high interest.

The Missile Defense Agency should examine the cost, risk, and benefit of alternative means of providing the needed global access for early launch warning and trajectory measurement for the integrated, layered system to include the potential contribution of SBR AMTI track capability.

Trajectory tracking

The Missile Defense Agency needs to include the trajectory tracking capability of the baseline SBR in plans for the overall sensor architecture for an integrated missile defense

Command and control and battle management integration

A decision to add new missions and capabilities to the SBR to serve the missile defense mission must be accompanied with specific changes to

the programs to provide integration of SBR information into command and control and battle management systems.

APPENDIX B: TERMS OF REFERENCE

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THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

FEB 2 2004

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board Task Force on Contributions of Space Based Radar to Missile Defense

In accordance with the National Defense Authorization Act for FY 2004, the Defense Science Board should assess potential contributions of Space Based Radar (SBR) to missile defense.

Recent studies done within the Department of Defense suggest that SBR may possess some inherent capability to detect, track, and discriminate ballistic missile warheads in flight. While the primary missions of SBR are moving target indication and synthetic aperture imaging, the high priority of ballistic missile defense may benefit from an assessment of the potential contributions by SBR.

The Task Force, in consultation with the Missile Defense Agency, shall

(1) Assess the impact of adding a missile defense mission on the ability of SBR satellites to conduct their primary missions;

(2) Assess how different SBR architectures and technical approaches might affect the ability of the satellites to achieve their primary missions and to contribute to missile defense;

(3) Assess the value of potential SBR capabilities in the context of the family of sensors being developed by the Missile Defense Agency; and

(4) Recommend any future actions that might be desirable related to SBR contributions to missile defense

The Study will be co-sponsored by me as the Acting Under Secretary of Defense (Acquisition, Technology and Logistics) and the Director, Missile Defense Agency. GEN Larry Welch, USAF (Ret.) and Dr. Bob Hermann will serve as Co-Chairmen of the Task Force. Mr. Gerald Augeri, Missile Defense Agency, will serve as Executive Secretary and LtCol Dave Robertson, USAF, will serve as the Defense Science Board Secretariat representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DOD Directive 5105.4, the "DoD Federal Advisory Committee Management Program," It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Michael W. Wynne
Acting

APPENDIX C: TASK FORCE MEMBERSHIP

CO-CHAIRMEN

Name	Affiliation
Dr. Robert Hermann	Global Technology Partners, LLC
Gen Larry Welch, USAF (Ret)	Institute for Defense Analyses

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APPENDIX D: GLOSSARY OF ACRONYMS

AMTI	Air Moving Target Indication
BM	Battle Management
C2	Command and Control
D3	Detection, Discrimination and Designation
DB	Decibel
DSB	Defense Science Board
DSP	Defense Support Satellite
HRTI	High Resolution Terrain Information
HPRF	High Pulse Repetition Frequency
ISR	Intelligence, Surveillance and Reconnaissance
LEO	Low Earth Orbit
MDA	Missile Defense Agency
MDV	Minimum Detectable Velocity
MEO	Medium Earth Orbit
SBR	Space Based Radar
SAR	Synthetic Aperture Radar
SMTI	Surface Moving Target Indication

TELS	Transport-Erector-Launchers
TPPU	Task, Post, Process and Update
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics